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Analysis of Eco-Hydrological Characteristics of the Four Famous Carps' Spawning Grounds in the Middle Reach of Yangtze River

Analysis of eco-hydrological characteristics of the four famous carps' spawning grounds in the middle reach of Yangtze River

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Abstract The four commercially important Chinese carps i.e. black carp, grass carp, silver carp and bighead carp are main catches in Yangtze River. In the recent two or three decades, the resources quantity of the fish declined enormously. There are many influenced factors, in which the large-scale water control project constructing is one of the most important reasons. In order to protect the four species and provide the basis for the large-scale water control project ecological operation, nine eco-hydrological indicators in the middle reach of Yangtze River, including the flow rise number, total flow rise days, starting stream flow, increasing rate of stream flow, continuous period of rising of water level in a flood period, et al. have been used and quantitative analyzed during the breeding season. It was found, there was no significant difference between the spawning grounds and common reaches for the nine indicators. It means that the selected indicators are only the necessary conditions for the four freshwater fishes spawning, but not the whole influencing elements.

Keywords Eco-hydrological index; eco-hydrological characteristic; the middle reach of Yangtze River; the four famous freshwater fishes; spawning ground

1 Introduction

Grass carp（*Mylopharyngodon piceus*）, black carp（*Ctenopharyngodon idellus*）, silver carp（*Hypophthalmichthys molitrix*）and bighead carp（*Aristichthys nobilis*）, usually called the "four famous domestic fishes" , are commercially important fish species with great catches in China. Yangtze River is an important natural spawning ground for the four famous freshwater fishes. Investigations in the 1960s indicated that, 36 spawning grounds spreaded from Ba County (Sichuan province) to Pengze county (Jiangxi province) covering a range of 1700km in the main channel of Yangtze River (Yi et al., 1998). According to the survey by Zhitang Yu et al. in 1986, there were 30 spawning grounds between Chongqing and Tianjiazhen (Hubei province), of which 11 above the SanDouPing with the egg production of 29.6%, 8 below the ChengLingJi with 27.7% and 11 between them with 27.7%. In addition, other four smaller spawning grounds were observed in Fuchikou, Jiujiang, Hukou and Pengze.

In the recent two or three decades, due to the lake isolation, river training and the large-scale water control project constructing, the habitat environment of the four famous freshwater fishes has been changed greatly. Under this condition, the quantity and scale of the spawning grounds reduced rapidly, and the resources quantity of the fish also declined enormously (Qiu et al., 2002). In order to protect the four species, four major surveys on the fish resources and habitats in Yangtze River in 1960s, 1970s, 1980s and 1990s were carried out, and changes of the four species and the influences of them by the large water control projects on the Yangtze Rive were available (Yu et al.,1985; Qiu et al., 2002). The investigation indicated that, there was a close relationship

between the four famous freshwater fishes spawning and the hydrology, the hydraulic conditions.

The hydrological regimes and flow conditions are the crucial factors for the four species spawning and growing, which can effect the fish habitat environment and the stimulative flow signals for fish spawning. In china, researches on the eco-hydrology and eco-hydraulic only just started. Chang et al. (1998) applied the factor-criteria system reconstruction analysis to research the reproduction of the four species in the Yangtze River. Li et al. (2005) analyzed the eco-hydrological factors and flow regime requirement on spawning of four major Chinese carps in the middle reach of Yangtze River, and ascertained renewedly the range of some fish spawning grounds with new method. Eco-hydrological indicators are generally recognized as the crucial factors which influenced the four species spawning by the fish experts. Although great deals of investigation works have been done, the quantitative conclusions that are the crucial eco-hydrological indicators affecting these species spawning have not been obtained. For the physical mechanism between the four species spawning and flow conditions is yet uncertain, it's unable to constitute exercisable ecological operation for the water control project. Thus, to ascertain the key flow conditions affecting the four species spawning is one of the most important research works.

2 The eco-hydrological characteristics

The different flows have different ecological effects in a river, which are usually divided into base flow, medium-and-high flow and flood flow. Base flow, the most basic limiting condition for the aquatic biological population in a river, is one of the most important kind of water flows, which can make the fish eggs and the amphibian float on the water surface. Medium-and-high flow mainly molds the natural shapes (riffle and deep pond) of the river, which can make the eggs hide in the boulders float on the water surface and protect it from burying. Flood flow can spur the fish to migrate and spawn, urge the life circulation into a new stage. Under this condition, the fish can spawn in the riffle, the fry can reach to the certain regions to grow and the aquatic animal can capture more opportunities to prey. Thus, different water flows have different influences over the spawning of the four fresh fishes.

The breeding season of the fish lasts from late April to late July in the middle reach of Yangtze River .The two most important factors controlling spawning are water temperature and water flow. The lowest water temperature of spawning is 18 ℃. If the water temperature drops below 18 ℃ during the breeding season, the spawning usually ceases even if flood happens (Cao et al., 1987). When the water temperature is above 18℃, it is not the factor that affects the reproduction scale of the four species (Yih et al.,1964; Cao, personal communication). Thus, water temperature was not considered in this paper because it was usually above 18℃ in the investigated breeding seasons in the middle reach of Yangtze River.

An increase of water flow is the triggering stimulus for the four species to spawn. Yih and Liang (1964) observed that spawning took place as the water level rising, but as soon as the water level started to recede, spawning action stopped immediately in the breeding season under the appropriate water temperature. Thus, to research the changes of the eco-hydrological indicators in a flow rise is the foundation to discuss the flow conditions which are the indispensable qualifications for the four species.

For the traditional hydrological indicators have been unable to attribute the significance of the ecology, it is urgent to confirm the eco-hydrological indicator of the river ecosystem. Zhang, G.

and Chang, J. (1998) used nine factors in the factor-criteria system reconstruction analysis to research the reproduction of black carp, grass carp, silver carp and bighead carp in Yangtze River. Based on the former research and the physical mechanism between the four species spawning and the flow rising, nine eco-hydrological indicators in the larvae-flood were analyzed in this paper. Total of these indicators were: flow rise number, total flow rise days, starting stream flow, increasing rate of stream flow, starting water level, increasing rate of water level, time interval between a flood period and a previous one, continuous period of rising of water level in a flood period and difference of water level amplitude between a flood period and a previous one. They were extracted and quantitative applied during the late April to late June.

3 Analysis of the eco-hydrological characteristics

After the water rises, the four famous freshwater fishes need certain time to spawn. The time gap is decided by the flow velocity which is usually 1-1.3m/s in the middle reach of Yangtze River. Under this condition, the species started to spawn in 1-2, even 3 days after the flow rised (1981). For the duration of the larvae-flood almost above four days, above continuous 5 days (contain 5 days) flow rise was defined as a flow rise in this paper.

On the basis of calculation by One-dimensional hydrodynamic model (Mike 11), the ten years' data of daily discharge and water level from 1997 to 2006 are available, which covers more than 600km between Yichang and Hankou in the middle reach of Yangtze River. Compared with the measured datum of Yichang, Shashi, Jianli, Luoshan et al. hydrologic station, the simulation results extremely approach to the actual value with the relative error smaller than 10%.

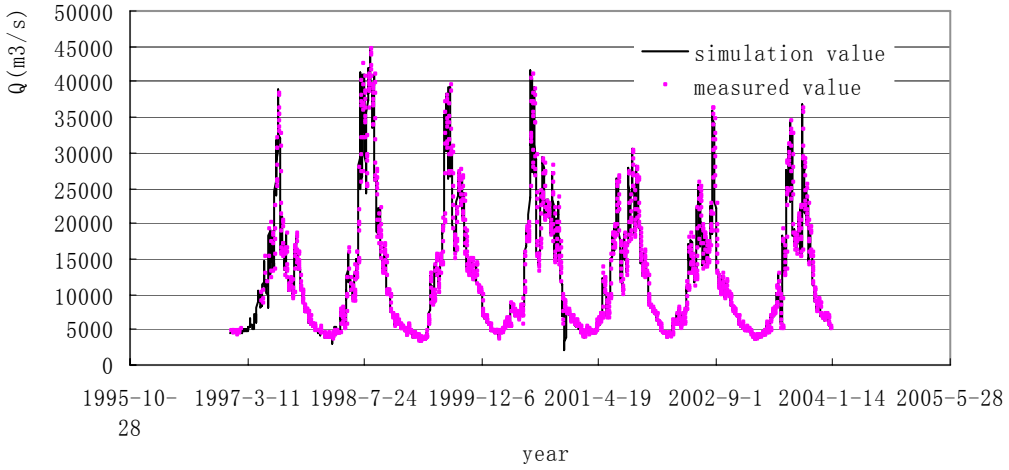


Fig1 simulation values and measured values of the flow in Jianli cross section

3.1 eco-hydrological characteristics in the spawning grounds and normal reaches

According to the range of historical spawning grounds, 59 cross sections of the flow and water level data were used, including 22 sections in the spawning grounds and 37 sections in the non- spawning ground reaches during the breeding season. Based on the simulation values by Mike11, the change tendency of the eco-hydrological characteristics and the difference of the nine eco-hydrological indicators between the two kinds cross sections were available along the river, the partial statistical results were shown in Table 1.

The significant eco-hydrological indicators are as follows: In Table 1, L1 represents the flow rise number; L2, Distance away from Gezhouba Dam; L3, starting stream flow; L4, increasing rate of stream flow; L5, starting water level; L6, increasing rate of water level; L7, time interval between a flood period and a previous one; L8, continuous period of rising of water level in a

flood period; L9, difference of water level amplitude between a flood period and a previous one .

Table 1some sections statistic of the eco-hydrological indexes multi- annual values in the breeding season

Distance away from Gezhouba Dam（km）	L1	L2 (d)	L3 (m^3/s)	L4 (m^3/s/d)	L5 (m)	L6 (m/d)	L7 (d)	L8 (d)	L9 (m)
40	3.1	22	4014.71~ 35620.74	134.459~ 5271.958	37.388~ 47.066	0.200~ 1.316	4~37	5~21	0.000~ 5.472
115 (Jiangkou)	2.4	15.8	3582.38~ 31358.38	91.564~ 7149.574	33.292~ 41.781	0.174~ 0.793	4~31	5~13	0.000~ 5.082
165 (Shashi)	2.5	17.1	4001.58~ 33295.27	126.762~ 6086.149	31.129~ 39.476	0.144~ 1.037	4~30	5~15	0.000~ 4.830
237 (Ouchikou)	2.5	15.6	5007.24~ 37274.50	91.653~ 5726.747	27.615~ 36.572	0.089~ 0.879	4~25	5~15	0.035~ 6.535
280	3.2	20	4412.93~ 37338.13	94.151~ 5596.291	25.656~ 35.400	0.142~ 0.753	4~29	5~19	0.185~ 6.513
315 (Jianli)	3.5	23.5	4538.99~ 37393.02	70.669~ 5044.848	23.843~ 33.608	0.177~ 0.851	4~27	5~19	0.428~ 6.124
350	3.7	24.3	4503.02~ 37404.54	39.983~ 6181.277	21.802~ 32.205	0.048~ 0.962	4~35	5~23	0.196~ 9.971
395 (Chenglingji)	3.5	35.9	8425.81~ 58928.26	290.503~ 4145.960	19.573~ 30.062	0.124~ 0.699	4~42	5~27	0.096~ 7.136
420	3.6	37.8	8701.54~ 58958.07	322.333~ 4143.996	18.118~ 29.341	0.118~ 0.710	4~42	5~27	0.084~ 7.254
492	3.6	38.9	11170.44~ 52705.68	287.626~ 3701.803	15.198~ 27.431	0.056~ 0.620	4~41	5~31	0.024~ 7.327

NOTE：The shadow parts are the statistical data of the historical spawning grounds sections

In the breeding season, the overwhelming majority of the four species spawn in the increasing flow, but certainly not all the rise can stimulate to spawn. Usually, a flood with longer duration or the second flood always cause a rapid increase in the number of the four species eggs, while the shorter duration or the first flood possibly can not be. The phenomenon indicates that it needs a long enough time or a continual flow rise before the four species spawning. The stimulation time is shorter if the flow velocity is rapid, vice versa.

The range of multi- annual flow rise number, total flow rise days and continuous period of rising of water level in a flood period is 2-4, 13-40d and 13-35d respectively, with increasing tendency along the reach. There are no obvious characteristic differences between the spawning ground cross sections and the normal ones, shown in the Fig 2-4.

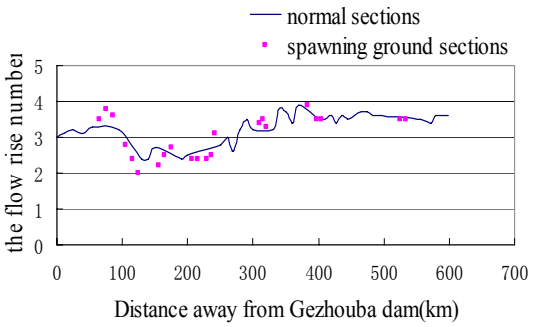


Fig 2 the flow rise number of the spawning grounds and normal sections

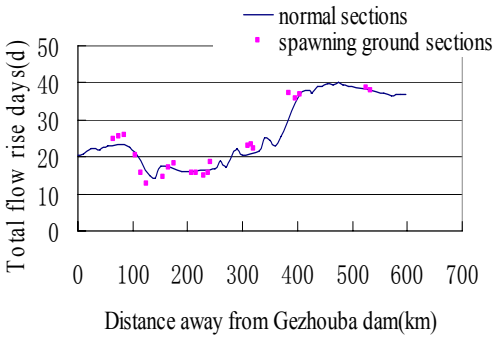


Fig 3 the total flow rise days of the spawning grounds and normal sections

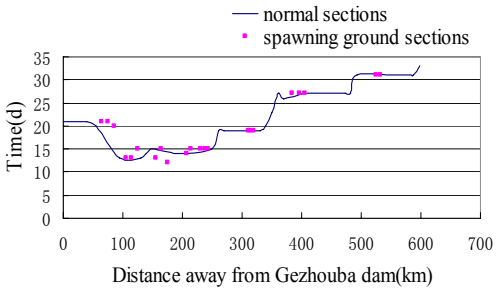


Fig 4 the continuous period of rising of water level in a flood of the spawning grounds and normal sections

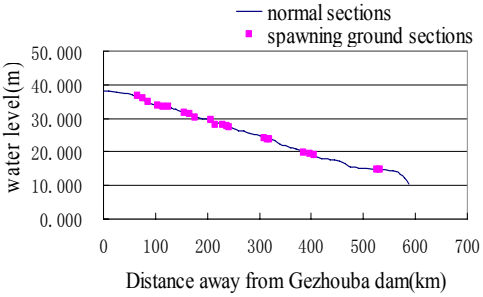
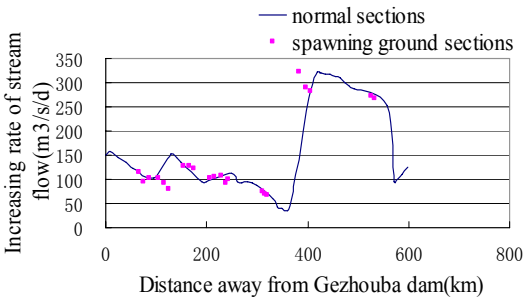


Fig 5 the starting water level of the spawning grounds and normal sections

Usually, the scale of spawning lies on the water level relative increase amplitude, but has nothing to do with the starting water level. In the prime breeding season from the first of May to the mid-June, the spawning scale has the direct ratio relation with the flow rise amplitude. If the flow rise amplitude is same, the spawning scale is also different under the different starting stream flow. There are no remarkable differences between the starting water level and the starting stream flow, the first index (Fig 5) reduces and the last one increases with the tendency along the study reach, respectively.

Based on the statistical data of most floods, it is found that the duration of flow rise sometimes completely coincides with the spawning duration, and sometimes the latter one is significantly shorter than the former. If the amplitudes of water level rise are same in two floods, the duration of spawning tallies better with the bigger increasing rate of water level. It can be seen from Fig 6-7 that the increasing rate of stream flow and water level is consistent with the overall trend along the 59 cross sections.



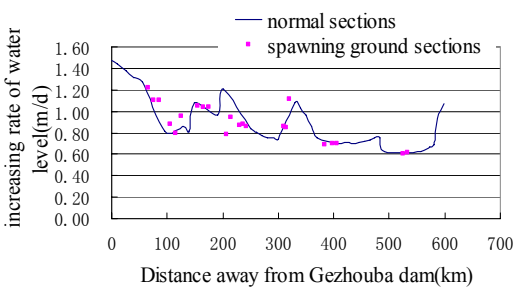


Fig 6 the increasing rate of stream flow of the spawning ground and normal sections

Fig 7 the increasing rate of water level of the spawning ground and normal sections

The foregoing analysis indicates that the change tendency of the selected 9 eco-hydrological indicators is consistent in the spawning ground cross sections and the normal ones along the reach, with no remarkable differences. The result shows that the selected eco-hydrological indicators are not the necessary and sufficient conditions to stimulate the four species to spawn.

Table 2 changes of eco-hydrological characteristics in the spawning ground and normal cross sections

Eco-hydrological indexes	No-spawning ground cross sections	Spawning ground cross sections	Differences
L1	3-4	2.5-4	No evident differences with the increasing tendency along the reach
L2(d)	15-38d	16-36d	No evident differences
L3(m^3/s)	4000-50000 m^3/s	3000-50000 m^3/s	No evident differences with the increasing tendency along the reach
L4($m^3/s/d$)	35.35-10667.84 $m^3/s/d$	66.6-14461.77 $m^3/s/d$	No evident differences in the two kinds sections, but Jiangli section is bigger
L5(m)	15-48 m	19-41 m	All of them reduce along the reach
L6(m/d)	0.05-1.4m/d	0.05-1.2m/d	the collectivity reduces along the reach
L7(d)	4-42d	4-42d	Basically consistent
L8(d)	5-31d	5-31d	No evident differences
L9(m)	4-6m	4-6m	No evident differences

In the previous researches, eco-hydrological indexes have been considered as the major influencing factors for the four species spawning, while this research shows that the trend of the nine selected indexes is consistent along the reach, without distinct differences. Although eco-hydrological characteristics in both spawning ground sections and no-spawning ground sections are satisfied with the four species spawning, the species choose to spawn in the particular regions, which indicate that the eco-hydrological characteristics are only the necessary factors for the four species spawning, but not the sufficient ones. Thus, it's extremely necessary to study the impacts of the eco-hydraulic indexes for the four species spawning besides the eco-hydrological indexes in the next research.

4 conclusions

On the basis of calculation by One-dimensional hydrodynamic model (Mike 11), the ten years' data of daily discharge and water level from 1997 to 2006 were available, which located between Yichang and Hankou in the middle reach of Yangtze River. 59 cross sections, including 22 sections in the spawning grounds and 37 sections in the non- spawning ground reaches, were

adopted as research objects. Nine eco-hydrological indexes, including discharge rise number, total discharge rise days, starting stream flow, increasing rate of stream flow, continuous period of rising of water level in a flood period, et al. had been extracted and quantitatively analyzed during the breeding season. It was found that there are no significant differences between the spawning grounds and abnormal reaches for the nine eco-hydrological indexes. It means the selected indexes are the necessary conditions for the four freshwater fishes spawning, but not the whole influencing elements. The results provide the important basis for the flow conditions of the four species spawning in the further research.

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